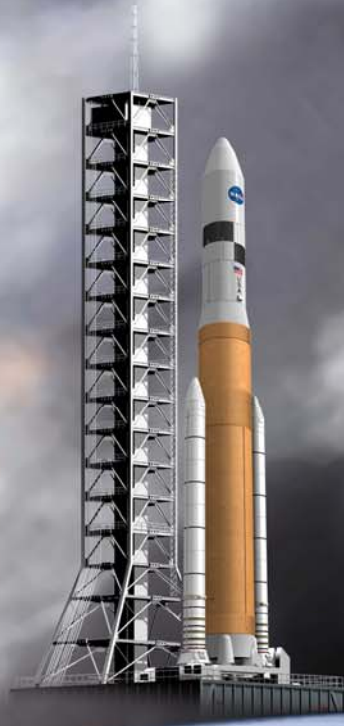
National Aeronautics and Space Administration

Marshall Space Flight Center
Digital Manufacturing

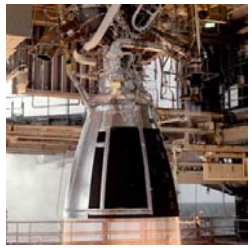


Ed Araya
Jacobs ESTS
EM40 Digital Manufacturing
10/7/08

www.nasa.gov

Marshall Space Flight Center

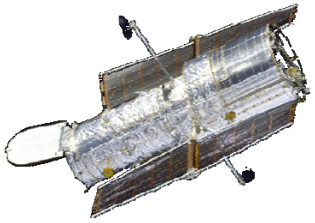
- **Established in 1960**
- **Employees: 7,000 (2,600 Civil Service; 4,400 contractor)**
- **Location: 1,841 acres on Redstone Arsenal in Huntsville, AL**
- **Buildings: 237 with 4.5M sq ft of space**
- **One-of-a-kind facilities: 50**
- **Nearby resources:**
  - National Space Science & Technology Center
  - Cummings Research Park
  - Alabama A & M University
  - University of Alabama in Huntsville
  - U.S. Space & Rocket Center



- **$2.7B budget (FY07)**
- **Part of NASA's nearly $1B annual Alabama impact**
- **Payroll since 1960: $6.1B**
- **Engages 20,800 people in 47 states**
- **Manages Michoud Assembly Facility near New Orleans**

Marshall Space Flight Center

- Development of the Saturn V rocket that transported the first humans to the moon
- Development of the space shuttle propulsion system
- Managing the development of Skylab, Spacelab, and International Space Station nodes.
- Managing projects such as the Hubble Space Telescope, the Chandra X-ray Observatory, and other scientific projects.
- Managing Ares I and Ares V of the Constellation program.

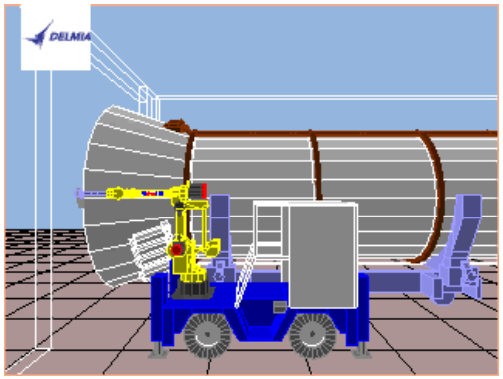


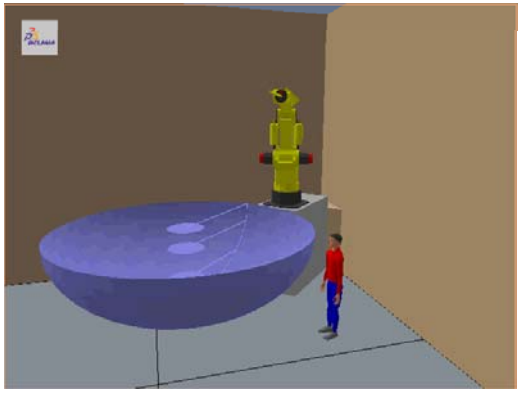
Outline

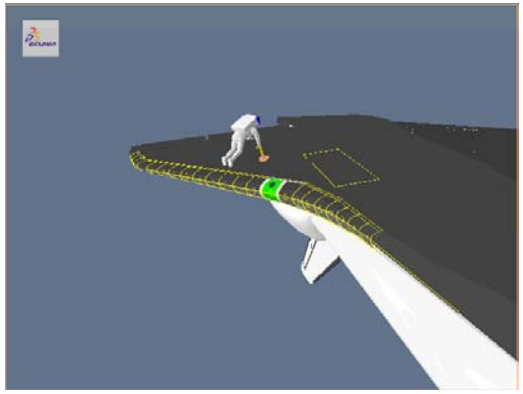
1. DELMIA History at MSFC
2. Constellation Program Overview
3. Ares I Upper Stage
4. Digital Manufacturing Implementation for Ares I US
5. Problems/Challenges We've Faced
6. Producibility/Simulation Analysis Examples

DELMIA D5 Legacy

- DELMIA has been in use at MSFC since 1986.
- The use of robotics, ergonomics, and assembly has been vital for the center in project studies as well as investigations.
- EM40 (Process Development)
  - ET – SOFI Process Development
  - SSME- MCC Weld Repair
  - SLI- Cryotank Producibility
  - SRB – Mobile Robotic System for KSC
  - RSRM – Waterblast Refurbishments
- EV10 (System Analysis)
  - SpaceHab RMS Reach Analysis
  - Nuclear Vehicle Proximity Operations
  - gLIMIT Snubber Interference Analysis
  - Quench Module Insert Operations
  - ISS Proximity Operations (APMAT)

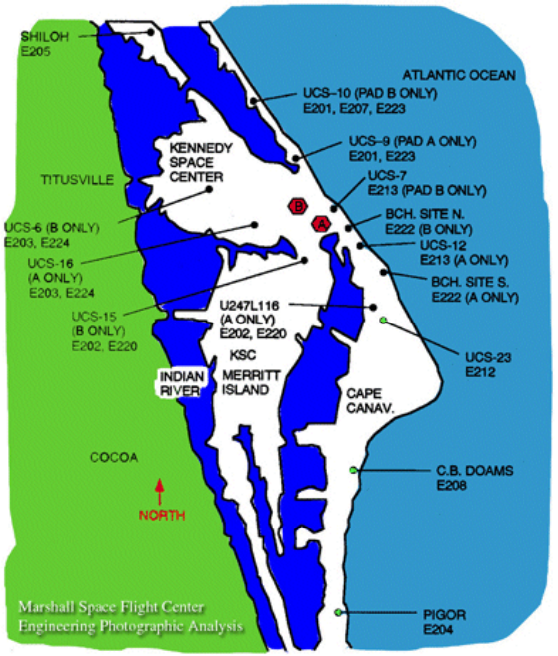


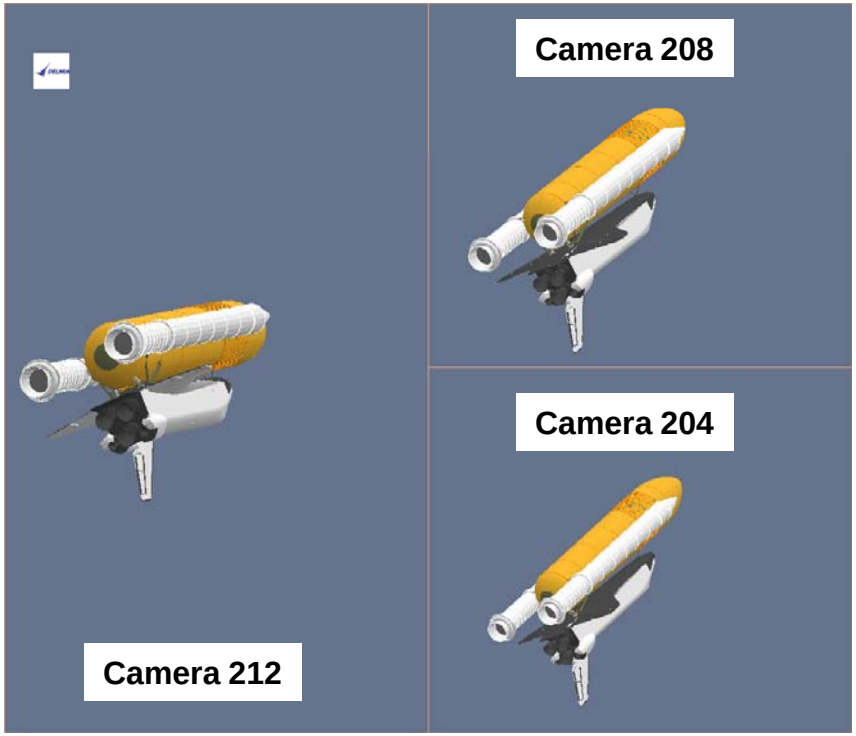




STS-107 Columbia Investigation

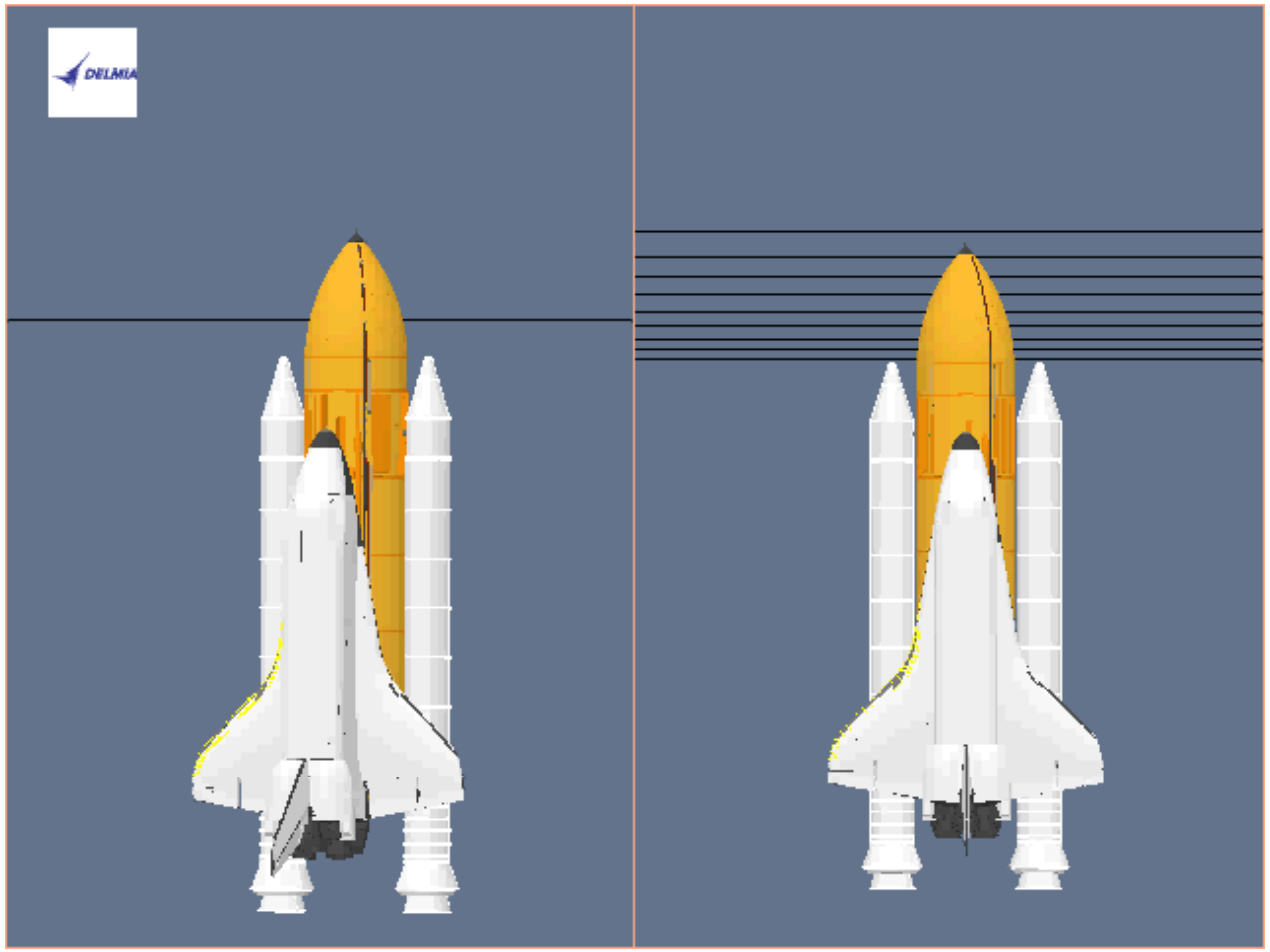
- TD53 - Video, film, trajectory data, and camera locations
- Task
  - Use existing film and video images to quantify position and velocity of the foam impact on the Columbia wing @ T+81 seconds.
- Goal
  - Generate a trajectory which does not violate the video.
  - Determine point, angle, and speed of impact.





Trajectory and Perspective Simulation

- Generation of 3-D virtual flight of Columbia during the first 82 seconds of the mission using imbedded trajectory data.
- Position virtual cameras in this environment to match the coordinates of physical camera positions and view angle with matched focal point.



Camera 212 Camera 208

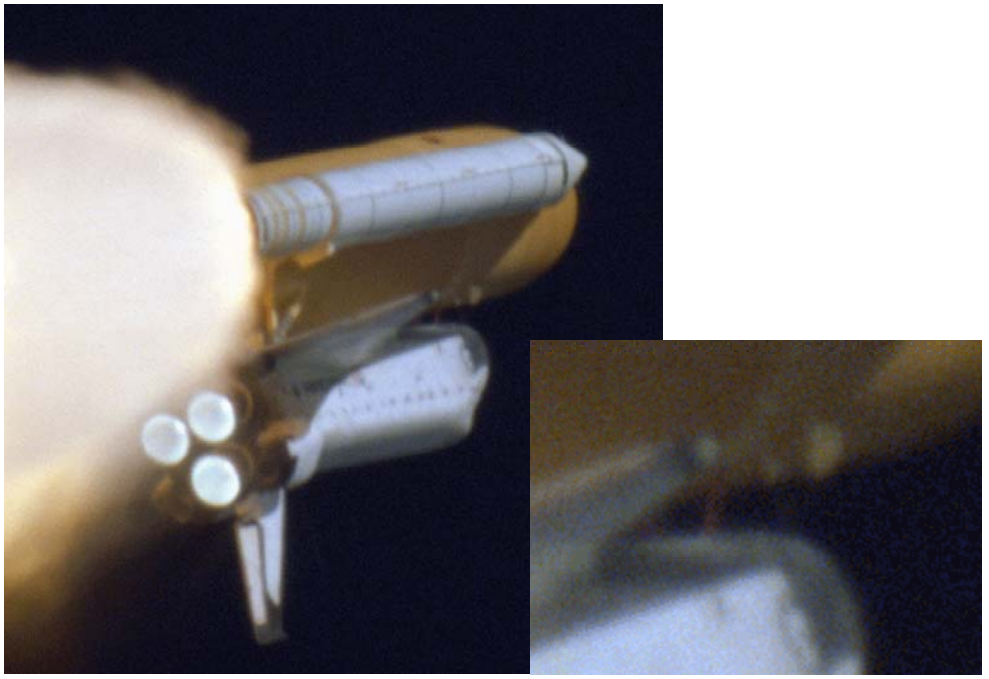
Line-of-Sight Vector Generation

- Match DELMIA model to video image.
- Move virtual foam ball until it aligns with red pixels highlighted by TD53.
- Draw a line from camera position to foam ball to generate line-of-sight vector.

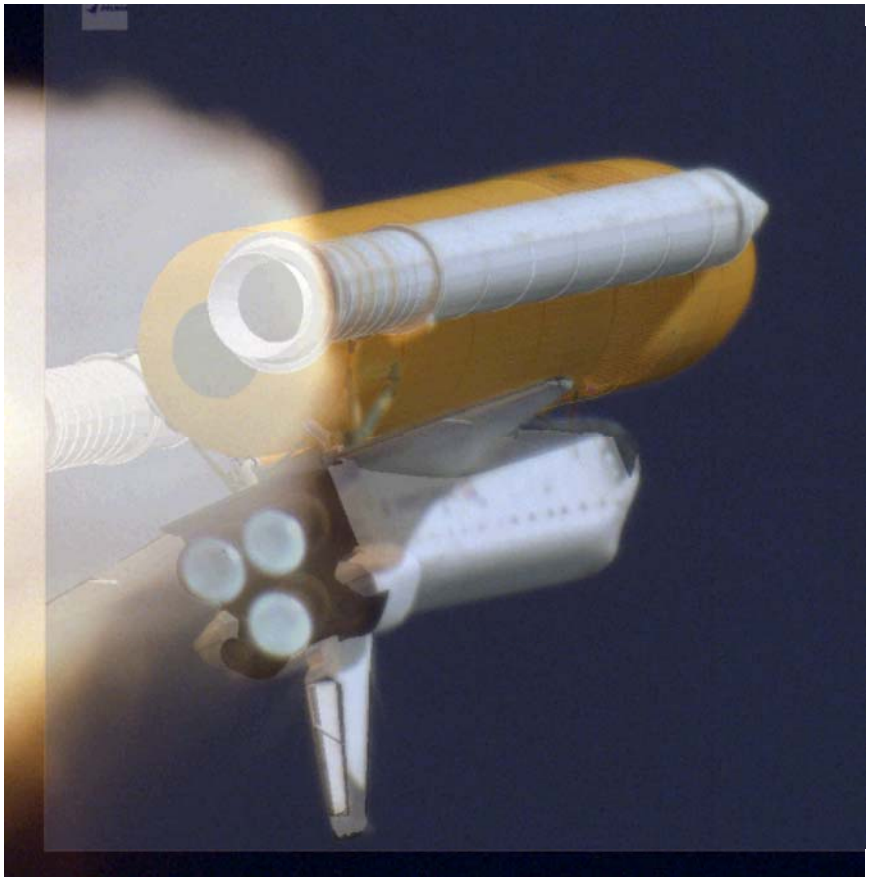
Original E212 File Video

DELMIA Generated Image

E212 File Video Merged with DELMIA Image



Conclusions



- Foam impacted in the region of RCC panels 7-9.
- Impact speed
  - 9.5 to 10 in/ms
  - 800 to 833 ft/sec
  - 545 to 567 mph

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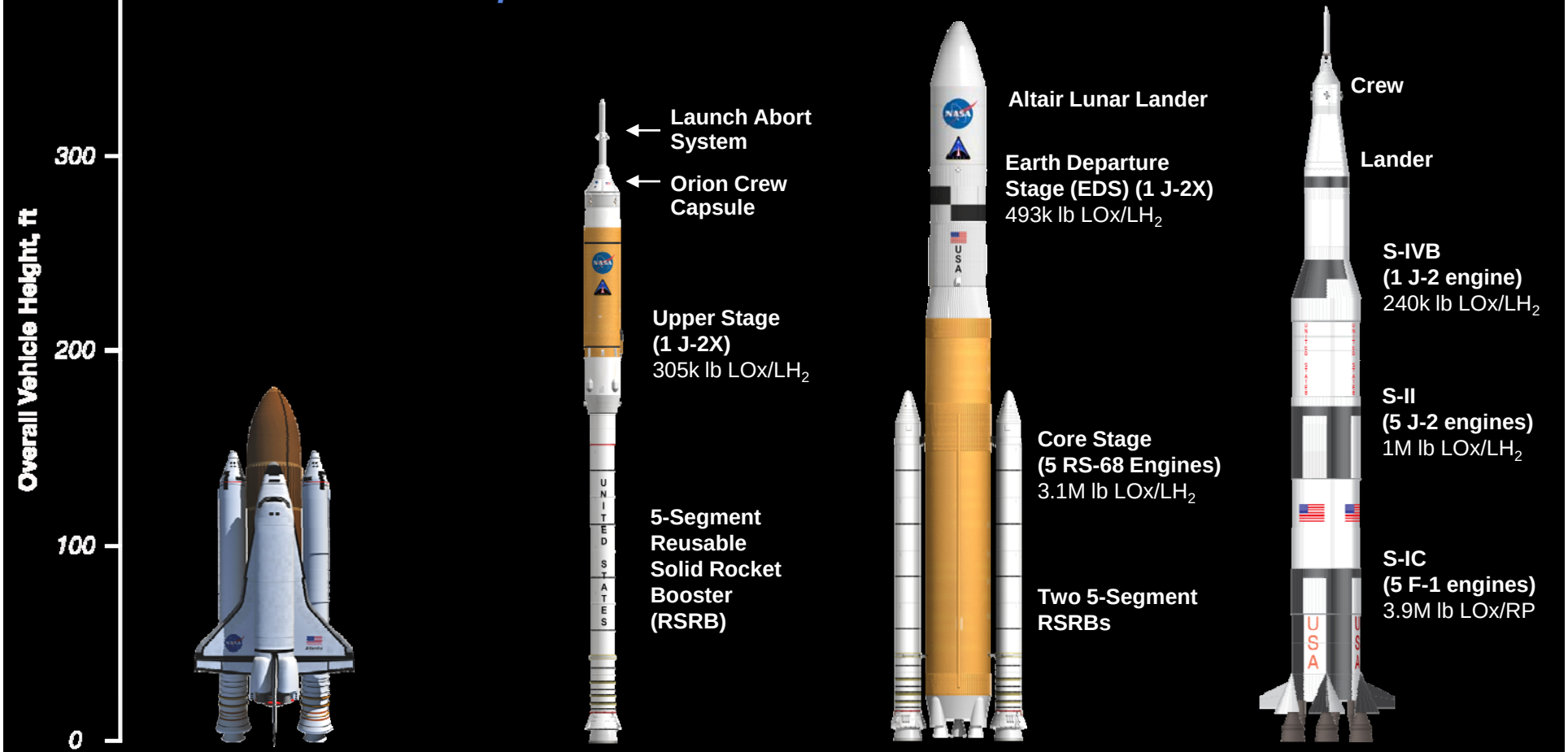
Vision for Space Exploration

- **The Vision for Space Exploration Program**
  - Was announced by President Bush on January 14, 2004
  - It basically called for the following:
    - Complete the ISS in 2010
    - Retire the Space Shuttle in 2010 after ISS completion
    - Replace the Space Shuttle with a new vehicle and fly it by 2014
    - Return man to the moon by 2020
    - Set the stage for a manned trip to Mars and Beyond
- **The Vision is now referred to as the Constellation Program**
  - Funding was not approved until 2005
  - It was late 2005 / early 2006 before work started to ramp up
- **Ares I**
  - The purpose of this vehicle is to lift astronauts to the ISS or to rendezvous with the Earth Departure Stage (EDS)
  - Was originally referred to as the Crew Launch Vehicle
- **Ares V**
  - This is the heavy lift vehicle which can lift satellites or other cargo to space
  - Will also deliver the EDS to orbit for rendezvous with the Orion capsule
  - Was originally referred to as the Cargo Lift Vehicle

Vision for Space Exploration

Evolutionary Space Transportation

Launch Vehicle Comparisons



Space Shuttle

Height: 184.2 ft
Gross Liftoff Mass: 4.5M lb

55k lbm to LEO

Ares I

Height: 328 ft
Gross Liftoff Mass: 2.0M lb

52k lbm to LEO
(effective)

Ares V

Height: 362 ft
Gross Liftoff Mass: 7.3M lb

119k lbm to TLI
133-144k lbm* to TLI in Dual-Launch Mode with Ares I
284k lbm to LEO

Saturn V

Height: 364 ft
Gross Liftoff Mass: 6.5M lb

99k lbm to TLI
262k lbm to LEO

**Note: Depending on length of on-orbit LEO loiter time*

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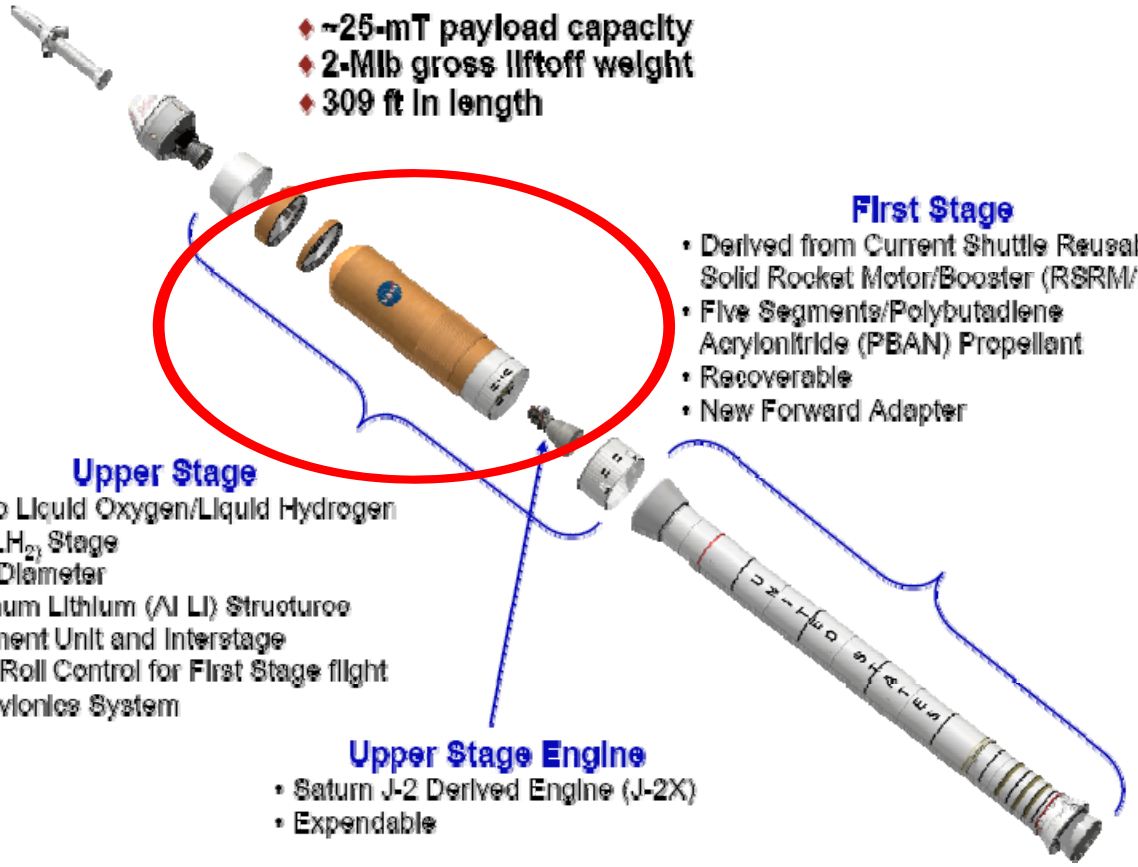
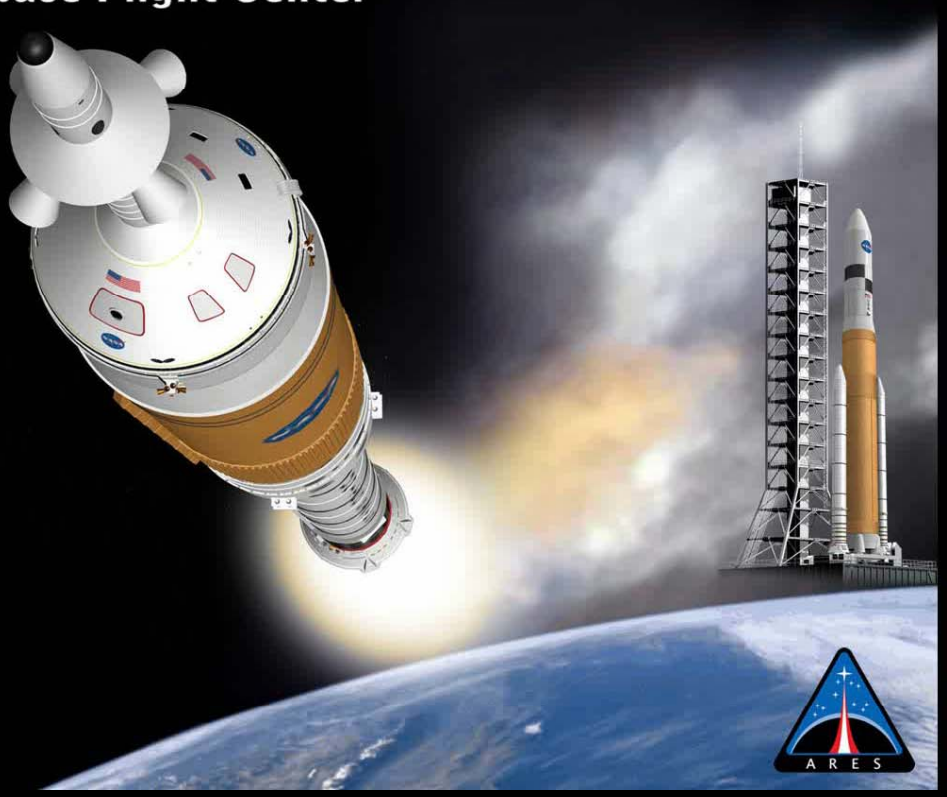
Ares I Upper Stage



Ares I Upper Stage

Ares I - Upper Stage Manufacturing Demonstration Articles

Marshall Space Flight Center



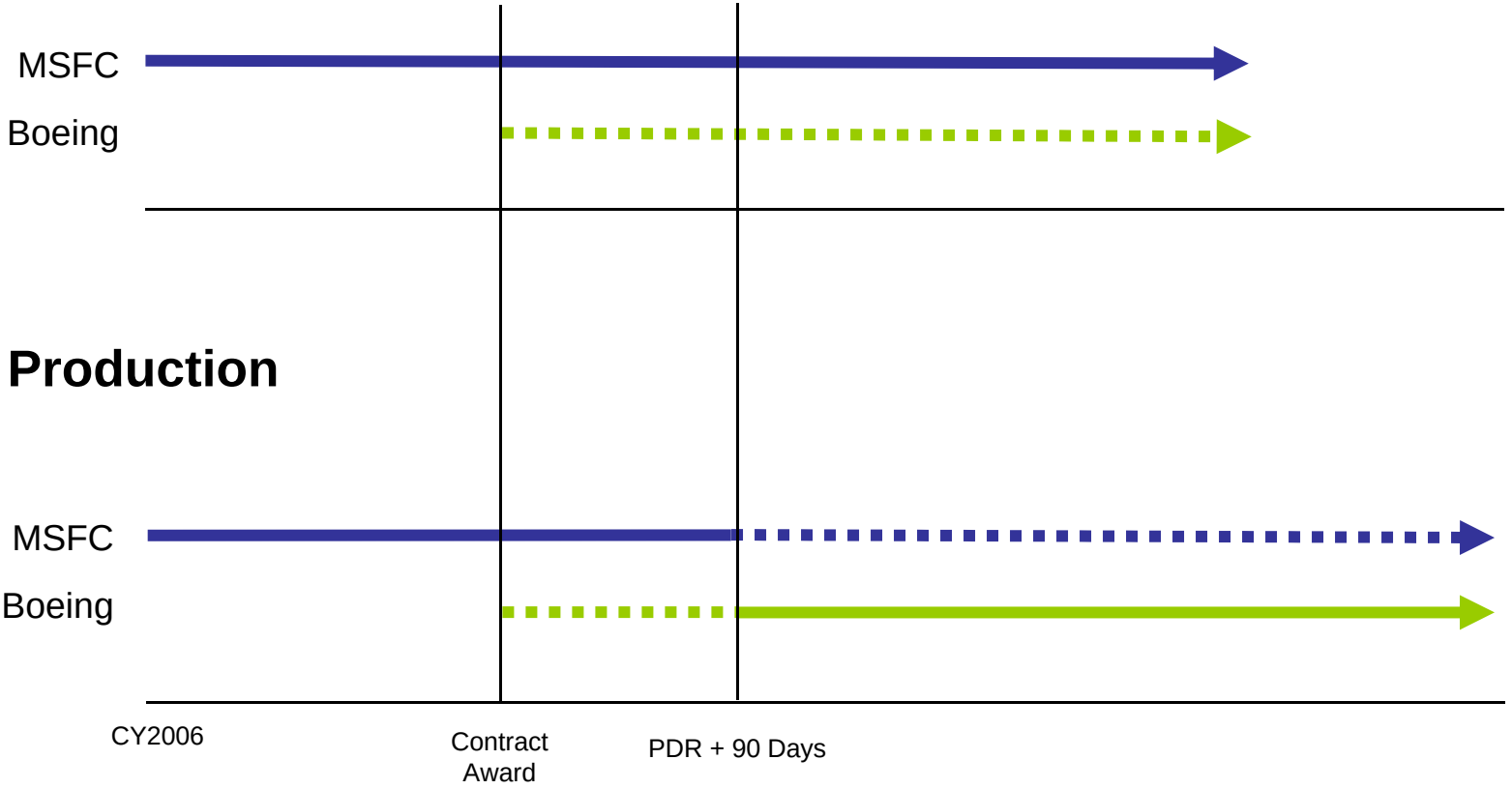
Preliminary Design Review (PDR)
June 6, 2008
Prepared by MSFC Materials & Processes Laboratory
NASA Sensitive but Unclassified (SBU)

Ares I Upper Stage Project

- **Ares I Production Contractors**
  - 1st Stage – ATK/Thiokol
  - Upper Stage – Boeing
  - Orion – Lockheed Martin
- **Ares I Upper Stage**
  - MSFC is responsible for the design and providing the M&A plan
  - The development program will occur at MSFC
  - Production will occur at the Michoud Assembly Facility (MAF) just outside New Orleans, LA
    - This is the current facility used to build the External Tank for the Space Shuttle Program.

Summary of Responsibilities

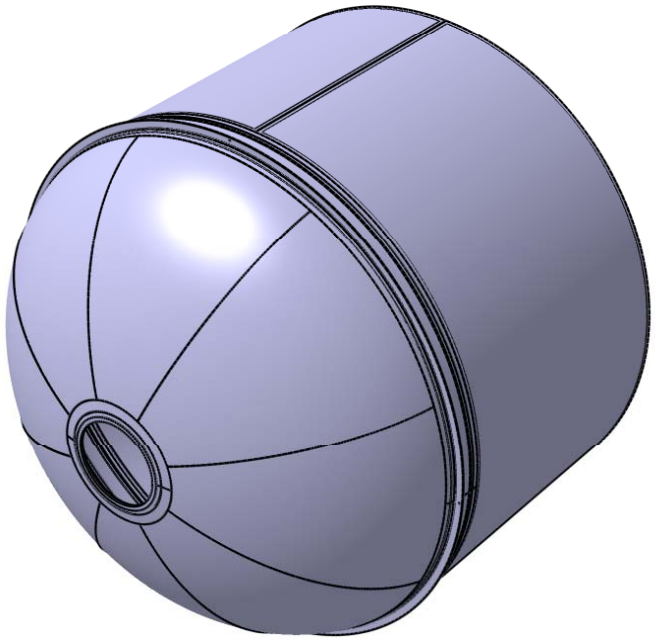
Development



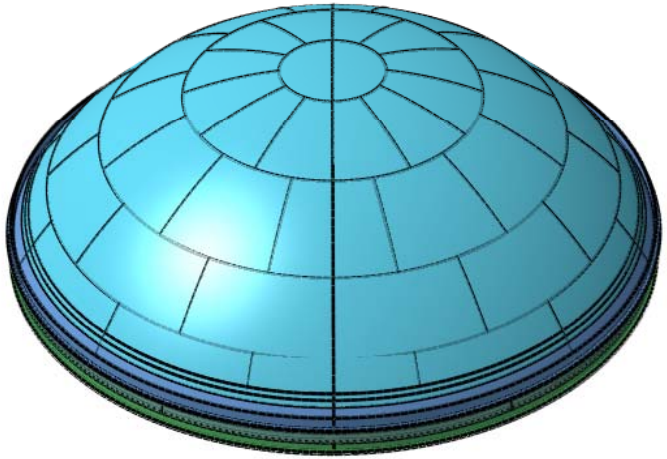
Production

Leading
Supporting

Manufacturing Demonstration Articles (MDAs)



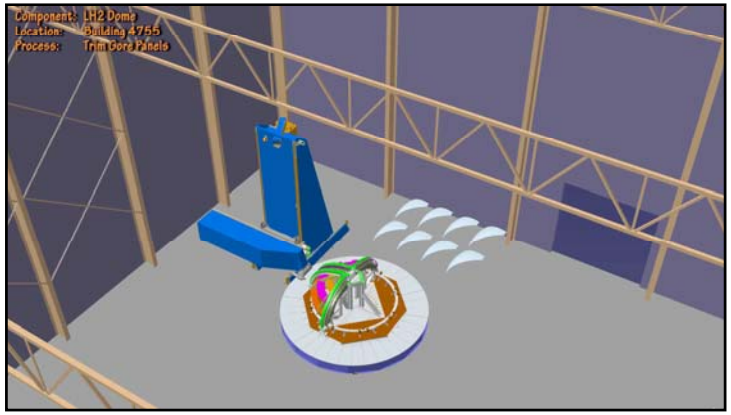
Manufacturing Demonstration Article (MDA)

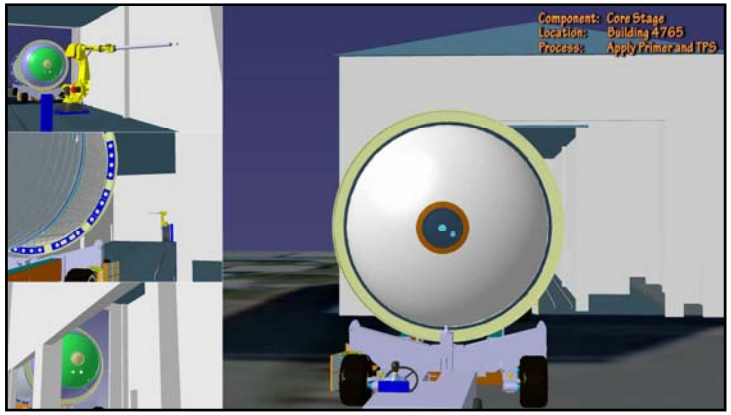


Common Bulkhead MDA

Demonstration Articles

- Robotics
  - 35’ tall 7-axis robot with 30’ diameter turn table.
  - Performs Friction Stir Welding of the Gore panels used to create the dome of the Upper Stage
- Upper Stage Assembly
  - Assembly of the Common Bulkhead
  - Human task simulation to conduct producibility analysis
- Spray Booth
  - 7-axis robot will apply primer and spray on foam insulation.
  - Use of DELMIA robotics and assembly package





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Digital Manufacturing Implementation

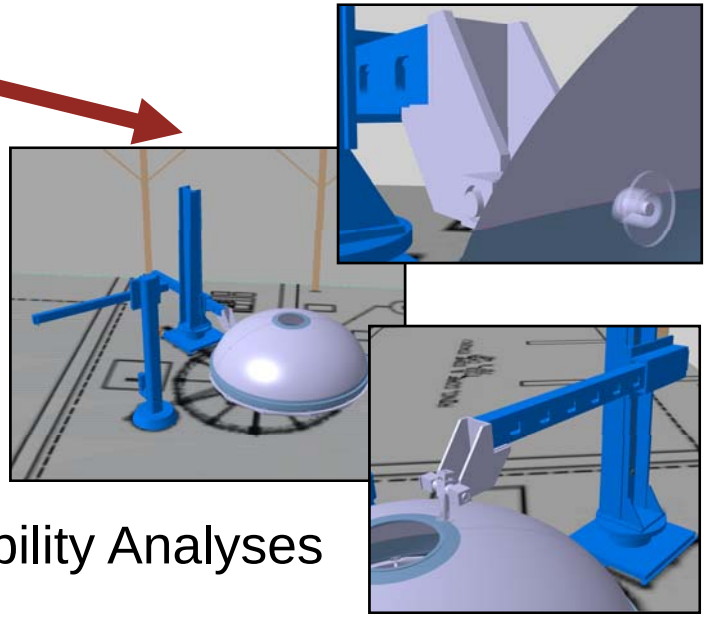
- **First step was to migrate from D5 to V5**
  - Developed a list of functions used in D5 which were required to exist in V5
  - DELMIA came in and we worked through this list
  - Not all items existed in V5, but we made the decision to migrate to V5 and retain some D5 licenses
- **Industry Benchmarking**
  - **November 7-8, 2006**
    - Tank and Automotive Research Development and Engineering Center (TARDEC) and General Motor Product Development Center, Detroit, Michigan
  - **November 15, 2006**
    - Boeing Integrated Defense Systems, San Antonio, TX
  - **December 6-7, 2006**
    - Boeing Commercial Group, Dreamliner Program (787), Seattle, WA
  - **January 10, 2007**
    - Boeing F-18 Program, St. Louis, MO
  - **January 24, 2007**
    - Flexial Corporation, Cookeville, TN

State of DM 18 Months Ago

DDMS
Source of Design Data

MSFC IES09
File Based Data Storage

Stand Alone
Workstations

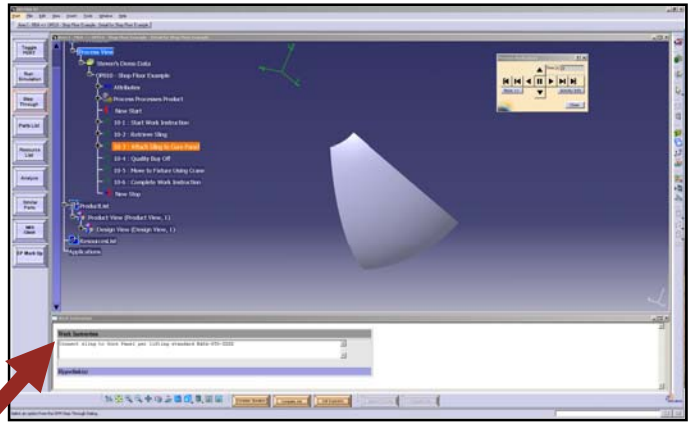


Producibility Analyses

Legend
- Manual
- Automated

Current State

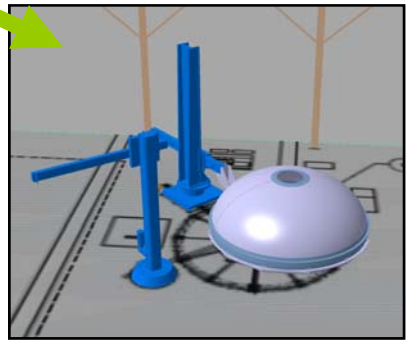
DDMS
Source of Design Data



Model-Based Instructions

Manufacturing Hub
Source of
Manufacturing Data

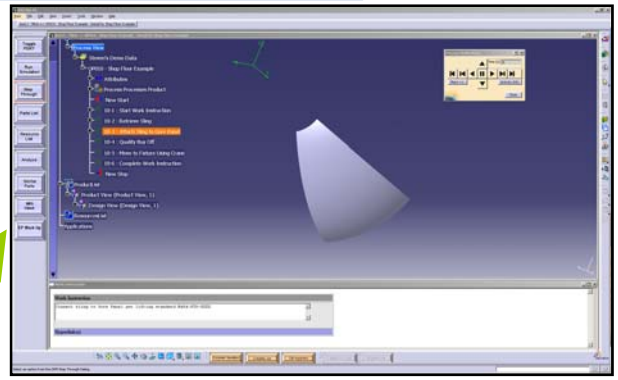
Stand Alone
Workstations



Producibility Analysis

Legend
- Manual
- Automated

The Future State

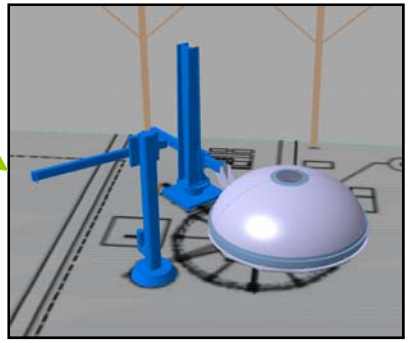


Model-Based Instructions

DDMS
Source of Design Data

Manufacturing
Execution System

Stand Alone
Workstations



Producibility
Analysis

Legend
- Manual
- Automated

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Problems/Challenges

- **Getting our Foot in the Door**
  - We had to do a lot of selling
  - Had to get the buy-in from our Project Office
  - Also had to let the design teams realize the value we could bring to the table
  - Time spent : ~ 12-14 months
- **We're NOT CARTOONISTS!**
  - Our simulations have been called animations, cartoons, illustrations, etc.
  - Constantly asked to provide "cartoons" for different presentations
  - Must play up your successes and tout the tool's real capabilities
- **Non-homogeneous Environment**
  - The design is created with Pro/E and housed inside Windchill database
  - The design changes without us knowing.
  - We've generated simulations, shown the results, and then been asked why we were using outdated models.
- **Design data in various locations**
  - All of the US design is in DDMS
  - Designs for fixtures, tooling, etc. are stored in various other locations.
  - Impossible to keep up with it all

Problems/Challenges

- **CAD Translation Problems**
  - This is one of our biggest problems
  - Can take 4-7 days to translate an assembly with 20,000 parts
  - We've tried the following:
    - 3DEvolution from Core Technologies
    - CADFix from ITI TranscenData
    - Theorem
    - Elysium (The new DELMIA translator as of R18)
    - MPP (The old DELMIA translator, pre-R18)
  - The best to date have been the DELMIA provided translators
- **Not Working in a Fully Model-based Environment**
  - Since NASA's inception, the 2D drawing has been the standard.
  - Moving from that has been difficult
  - For Ares I US, the decision has been made to move to a hybrid environment
  - Models will be provided; metal can be cut to those models
  - However, all notes and annotations will be on the drawings, NOT the model
- **Lack of a Enterprise Manufacturing Execution System**
  - Visual Manufacturing used by our machine shop
  - Very antiquated interface and functionality
  - Does not capture electronic signatures
  - Does not offer an interface with DELMIA

Problems/Challenges

- **Development of Model-Based Instructions and Standards**
  - Many of the functions in V5 used to create Model-Based Instructions lack desired functionality.
    - 2D Annotated Views – Do not work in R17 or R18
    - Standard Libraries for Work Instruction Text – Can be created in V5, but not modified
    - Shop Floor Interface – Window sizes have apparently been hard-coded; Hampers customization.
  - Using Panasonic Toughbooks on the Shop Floor. Delays from our IT group in developing a standard software load which meets NASA IT Security requirements.

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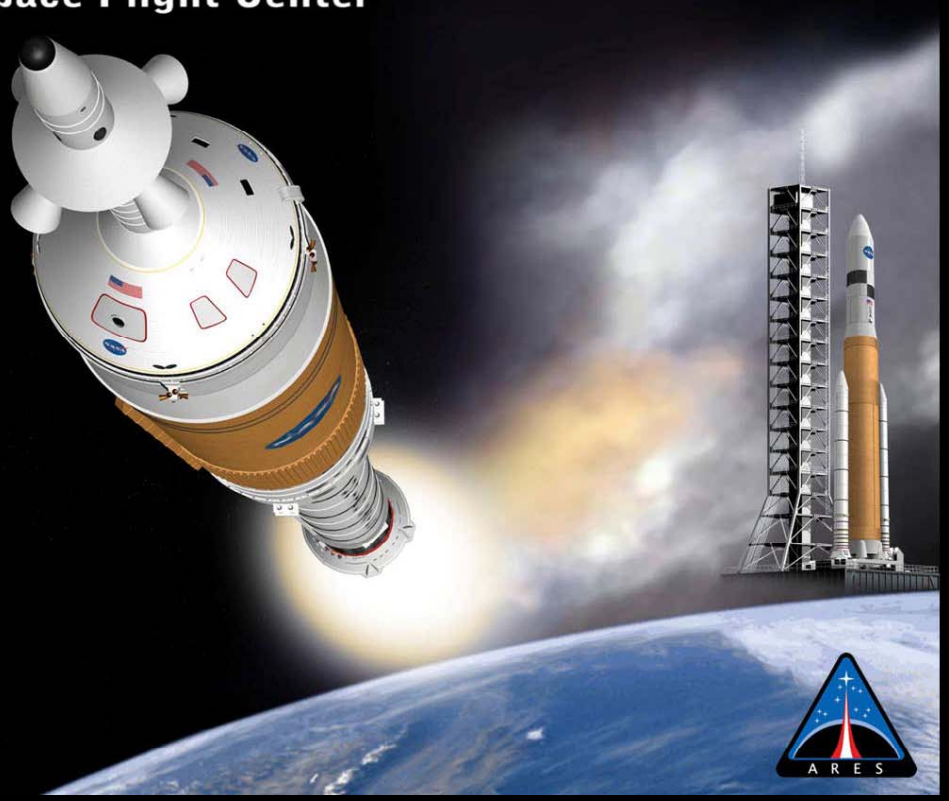
MSFC Simulations

Ares I - Upper Stage Manufacturing Demonstration Articles

Marshall Space Flight Center



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Thank You